

# The Influence of the Highway Network Structure on the Economic Development of West Virginia

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A procedure is proposed to consider additional information in the evaluation of alternative transportation systems when the main objective of the improvements is to increase the economic growth of a stranded area. The effect of transportation improvements on the economic development of Appalachia is discussed within the context of the Appalachian Regional Development Act. It is concluded that the objective of the Act is to increase the economic growth of Appalachia by concentrating public investments in growth points and attracting new industry. Transportation improvements can help achieve these goals by increasing the locational advantage of growth points relative to major metropolitan centers. West Virginia is presented as a case study.

●OVER the past decades, Appalachia has become synonymous with underdevelopment and has been a problem area within the national economy. The Appalachian Region includes West Virginia and parts of 12 other states. (The Appalachian Region was so defined in the Appalachian Regional Development Act of 1965 and amendments. The definition includes those counties in the states that share the same social and economic problems.) The region can be described as an area of gently rolling to mountainous terrain with a large nonurban and nonfarm population, a population growth below the national average, high unemployment rates, and a low level of public expenditures and services.

Appalachia has continually been used as an example of a stranded area within a highly developed economy. The Region has lagged behind the remainder of the United States in terms of economic growth and ability to adjust to economic changes. In 1965, Congress passed the Appalachian Regional Development Act (ARDA) to provide federal assistance in meeting the Region's special problems and in promoting its economic development.

Transportation improvements play a key role in the federal program for Appalachia. In 1964 the President's Appalachian Regional Commission recognized the importance of increased accessibility to foster economic growth by recommending adequate provision of access by highway and air, both to and within the Region, as one of four priority areas of investments. As a result, ARDA authorized the construction of an Appalachian Development Highway System supplemented by local access roads. ARDA emphasized transportation improvements as a means of stimulating development and further specified that "public investments... shall be concentrated in areas where there is a potential for further growth" (1). The planners and administrators in charge of carrying out the provisions of ARDA were then given a clear and explicit statement of goals and means to attain them. The goal of promoting the economic growth of the Region

was to be accomplished by public investments, especially transportation investments, in those areas with the greatest potential for growth.

Immediately, questions arose as to the relationship between transportation and economic development. Through ARDA, Congress directed planners to use transportation to achieve specified development objectives. Yet, the tools were not available to the planners. Most decisions to improve transportation facilities have been predicated on the forecast of transportation demand based on existing trends. Construction priorities have usually been based on the greatest benefits to users or on the greatest needs. A new approach was needed to make decisions on transportation improvements according to the ARDA requirements. However, the actual selection of the Appalachian Development Highway corridors was based on satisfying the forecast demand predicated on existing trends. The concept of a changing demand as a consequence of providing new linkages between Appalachia and the surrounding regions was not considered.

The measurement of changes in the locational advantage of places is presented in this paper as one technique presently available to the transportation planner that can be of assistance in evaluating the effects of alternative transportation improvements. Adequate consideration of this type of information is especially critical when the main objective of transportation investments is to stimulate economic development.

### APPALACHIAN DEVELOPMENT CONCEPTS

The concept that transportation improvements result in immediate economic development is erroneous. In most cases where a transportation improvement did stimulate rapid development, a combination of other factors was also present. For example, railroad construction stimulated the development of the West, but the same type of development could not have taken place if rich mines, dense forests, and vast resources had not been present (2, 3).

In the Appalachian Region, most natural resources are already being exploited. Zwick has posed questions concerning the magnitude of the impact from transportation improvements in an advanced economy like the United States. He stated that "there is now a relatively ubiquitous supply of transportation in all areas of the United States; and as a result, most future economic growth can be expected to be rooted in forces exogenous to the transportation industry" (4). The problem facing transportation planners in charge of selecting transportation improvements according to the requirements of ARDA can be summarized in the form of a question: How can transportation improvements stimulate development in a stranded area such as the Appalachian Region in which natural resources are being exploited? This question can be dealt with by analyzing the specific development problems of the Appalachian Region within the context of ARDA.

ARDA was based on the concept of stimulating development of a stranded area by public investments. However, Congress was aware that the problems of the Appalachian Region are too large to be solved entirely by a governmental program. Therefore, ARDA specified where investments should be made and how they were to stimulate development, so that in the future the Region could support itself:

The public investment made in the Region under this Act shall be concentrated in areas where there is a significant potential for future growth, and where the expected return on public dollars invested will be the greatest . . . Congress expects that the Region will generate a diversified industry, and that the Region will then be able to support itself, through the workings of a strengthened free enterprise economy (1).

In effect, ARDA applied the growth point theory of economic development to the problems of the Appalachian Region and specified the type of development that the Region should attract.

The growth point theory of economic development is based on the realization that the problems of development are too large to be solved by a "balanced growth doctrine" of equal aid to all regions and political subdivisions. This regional development strategy aims at integrating more developed areas with less developed areas through the location of economic activity. The objective is then to select a few high-potential growth points where investments can be concentrated in an attempt to bring neighboring areas within the orbit of development (5).

Congress also specified the type of development that should be attracted by stating that the Region should generate a diversified industrial base. The importance of this statement is obvious from a close look at the economic problems of the Appalachian Region. The high unemployment rates prevalent in Appalachia have been a result of an economy based on extractive industries. A shift to a diversified economic base is essential for economic growth to take place. The Region can diversify and prosper only by attracting new industries (6, 7).

Friedmann has noted that "accessibility to product markets has become the most significant single issue in location decisions within the United States" (8). He also points out that most new industrial locations are in or near metropolitan regions, whereas the locational potential of other areas has been declining. An increased accessibility to markets is then a prerequisite for the economic growth of the Appalachian Region. Furthermore, those areas with a greater locational advantage relative to regional markets have a greater potential for growth.

The transportation network of a stranded region such as Appalachia can be of assistance in achieving regional development goals in two ways: (a) an analysis of the existing transportation network can help identify the growth points with the greatest development potential; and (b) the existing transportation system can be improved in order to increase the accessibility to markets of the growth points previously selected. The selection of growth points should be based on human resources and available infrastructure, in addition to the accessibility factors.

Not all transportation improvements will increase to the same extent the accessibility to markets of the Appalachian Region. The objective, as expressed in ARDA, is to select those transportation improvements that will result in the greatest increase of the locational advantage of areas of high growth potential relative to regional markets. It is expected that the remaining areas within the Appalachian Region will become integrated with the more developed areas so that, in the end, the investments made will benefit the entire Region. Furthermore, the aim is to diversify the economy of the Region by attracting new industries. Transportation improvements can help attract new industry by increasing the accessibility of the Region to major markets and, therefore, this type of investment is emphasized.

ARDA has directed planners to develop an Appalachian Development Highway System supplemented with local access roads that would best serve the objective of promoting the economic development of Appalachia. The aim of the Appalachian Development Highway System is to increase the locational advantage of Appalachia by providing better direct connections between high-growth potential areas in Appalachia and major metropolitan centers outside Appalachia. The local access roads would then connect the major centers in Appalachia to the remainder of the Region.

Based on these regional goals, a procedure will be developed to assist in the evaluation of alternative transportation systems. The objective is to make use of analytical techniques that reflect the strong regional goals expressed in the Appalachian Regional Development Act.

#### WEST VIRGINIA: A CASE STUDY

West Virginia is the only state defined by the Appalachian Regional Development Act as being totally within Appalachia. Prior to World War II, West Virginia's economy was mainly dependent on coal mining and agriculture. Since that time, a major readjustment in the economy has been taking place while the state has been losing population owing to inadequate employment opportunities. Mining was the single largest industry in 1948 when employment reached a high of almost 125,000. By 1963, this figure dropped to 44,500, both because of a reduction in the demand for coal and an increased automation in the mines. At the same time, manufacturing and trade have become the most important of West Virginia's economic activities. However, the level of manufacturing and trade activity in West Virginia still remains less than the national average (9).

#### Assumptions

Certain assumptions are made in order to calculate indices that reflect the manner in which transportation improvements can influence future development. First, it is

assumed that the future economic development of West Virginia is dependent on attracting new industry. Within a highly developed economy such as the United States, industries become market oriented, and West Virginia must increase its accessibility to regional markets in order to compete with other areas.

Second, it is assumed that the future economic development of West Virginia depends on the provision of better services to the population, because West Virginia must compete with major metropolitan centers in attracting new industry. A need exists within the state to expand urban centers in order to provide more and better public services.

Third, it is assumed that areas outside Appalachia already have good access to markets, whereas the accessibility to markets of West Virginia will be substantially increased by improvements in the transportation system of the Appalachian Region. The existing transportation system of West Virginia does not provide a high level of service in linking the major centers of the state with surrounding areas. The transportation improvements now under construction will greatly change the accessibility patterns of the Region.

Finally, only the highway portion of the transportation system is considered in this paper. Taking into account the magnitude of investments in the highway system relative to the other modes, it can be concluded that the effect of other modes on the future development of the state will be minor.

### Growth Points and Regional Markets

A growth point has been defined as an area where growth has been occurring over a period of time and where this growth could be reinforced to stimulate the economy of the surrounding region (5). The Economic Development Division of Litton Industries conducted a study in 1965 to identify areas of growth potential in the Appalachian Region. This study concluded that urban areas "are consistently associated with higher levels of activity," and, therefore, synonymous with a higher growth potential (10). Based on

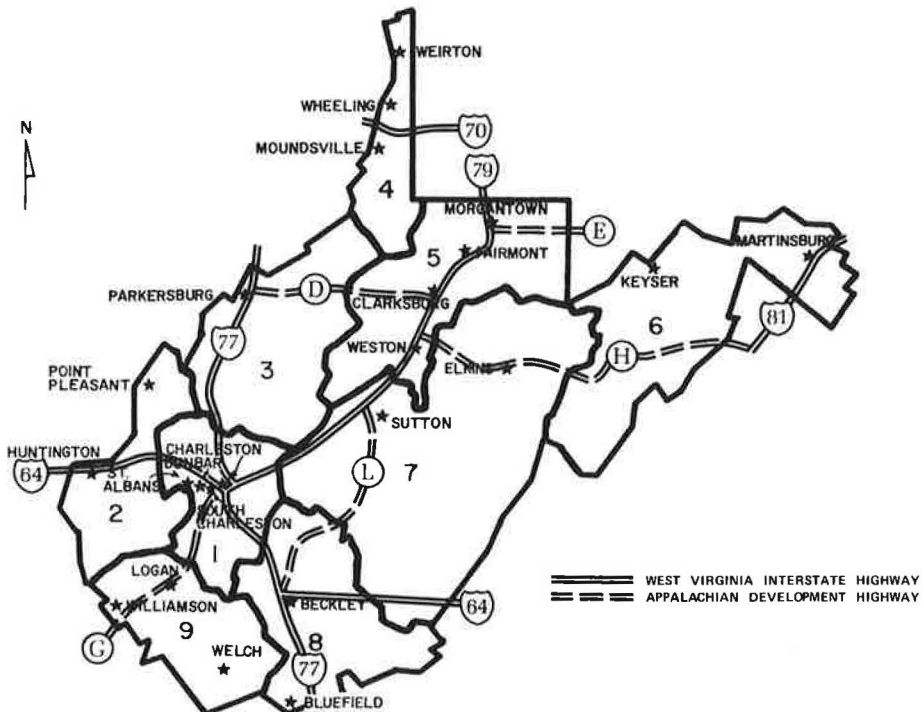


Figure 1. West Virginia subregions and major cities.

these results, all major cities in the nine subregions of West Virginia were selected as growth points. The nine West Virginia subregions are shown in Figure 1 as delineated by the Office of Research and Development at West Virginia University based on the boundaries of administrative districts, watersheds, economic characteristics, population characteristics, housing, and transportation facilities. Twenty-three urban areas or potential growth points were identified for the nine subregions of West Virginia (11).

Major and minor regional markets outside of West Virginia were defined on the basis of the size of the Standard Metropolitan Statistical Area (SMSA) and the distance from Charleston, West Virginia, the government center of the state. Those SMSA's with a population over one million and located within 250 miles of Charleston, or with a population of over 500,000 and located within 150 miles of Charleston were defined as major markets. Only six metropolitan areas, all located near the northern and western portion of the state, were identified as major markets. SMSA's with a population greater than 300,000 and located less than 150 miles from Charleston, and those metropolitan areas with an SMSA population greater than 15,000 and located within 100 miles from Charleston were added as additional minor markets. The following analysis first considered only major regional markets, and then both major and minor regional markets together. Figure 2 shows the major and minor regional markets, the West Virginia growth points selected for this study.

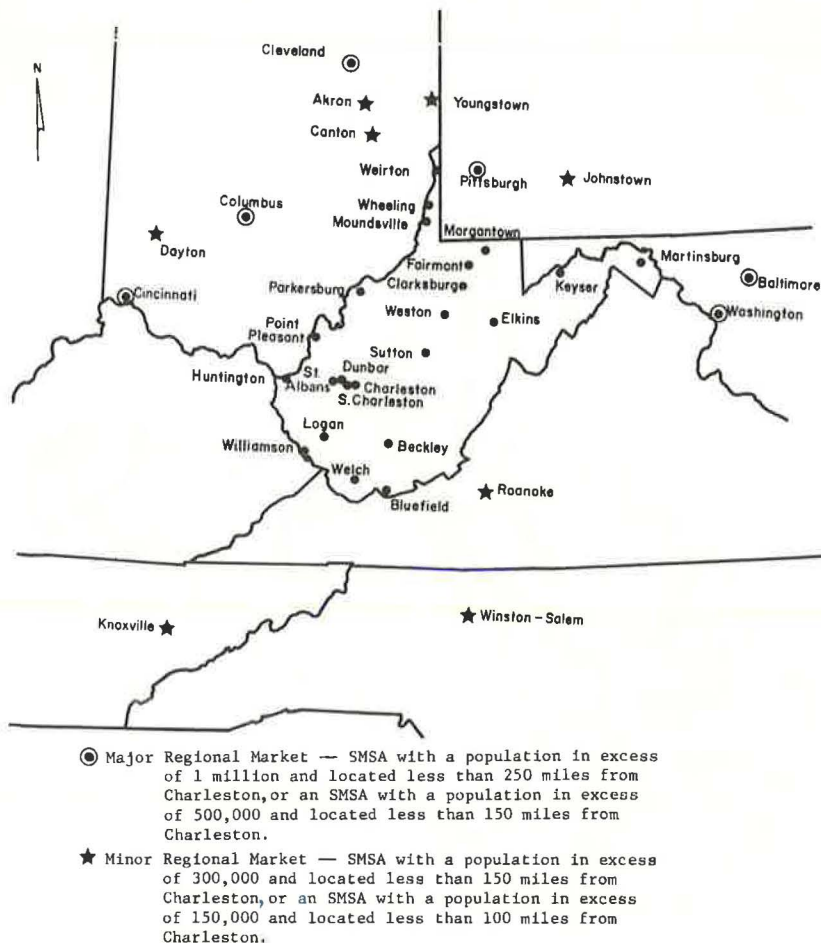


Figure 2. West Virginia cities and major and minor markets.

## West Virginia Highway Network

The West Virginia highway network has lagged behind the rest of the nation, mainly because of the problems encountered in attempting to finance public services within a depressed economy and because of the high cost of road construction in mountainous terrain (12). As shown in Figure 1, two new highway systems are presently being constructed in West Virginia: the National System of Interstate and Defense Highways (517 miles to be constructed at a cost of \$900 million), and the Appalachian Development Highway System (426 miles to be constructed at a cost of \$618 million). In effect, the Appalachian Development Highway System supplements the Interstate System by providing access to those areas that are not well served by the Interstate System.

By analyzing the highway network at three points in time and by analyzing two alternative future systems, three separate effects of highway improvements are discussed:

1. The change in locational advantage of West Virginia growth points during the construction period of the Interstate System was measured by comparing the 1965 System, including only some completed Interstate sections, with the 1950 base highway network.

2. The impact on the locational advantage of West Virginia growth points resulting from completion of the Interstate System was measured by comparing the 1975 network, assuming only the completion of the Interstate System (1975A network), to the 1950 base and the incomplete 1965 network.

3. The effect on the locational advantage of West Virginia growth points resulting from completion of both the Interstate and Appalachian Highway Systems was measured by comparing the 1975 network, assuming the completion of the Interstate and Appalachian Systems (1975B network), to the 1950 base, the 1965 incomplete, and the 1975A network.

## The Structure of the Highway Network—Indices of Locational Advantage

Graph theoretic measures describing network structure have been applied to transportation networks by other authors in recent years (13, 14, 15, 16). One of these indices was considered appropriate to characterize the structure of the West Virginia highway network in order to measure the locational advantage of growth points in the state. An additional index similar to a gravity formula was also included.

Accessibility—The accessibility index, with minor modifications, is a measure of the locational advantage of growth points in West Virginia with respect to regional markets. The accessibility index is defined as:

$$A(i, M) = \sum_{j=1}^M t_{ij}$$

where

$A(i, M)$  = accessibility of growth point  $i$  to  $M$  regional markets,

$t_{ij}$  = minimum path travel time from growth point  $i$  to  $j$ th regional market,

$i = 1, 2, 3, \dots, n$  (growth point in West Virginia), and

$j = 1, 2, 3, \dots, M$  (regional markets outside West Virginia).

This index is similar to the traditional graph theoretic accessibility index, except for two modifications. First, travel time in minutes is used rather than distance. In West Virginia, the level of service provided by the highway network can best be reflected by driving speeds, mainly because of the wide divergence in driving speeds found on the state's highways. Freeway travel averages 60 mph, but travel on the predominant two-lane winding roads ranges from 25 to 45 mph. Second, accessibility is defined to only  $M$  regional markets rather than all other places in the network, because only the locational advantage relative to markets outside West Virginia is hypothesized to influence development.

Interaction Potential—It is apparent that the above index has the inherent shortcoming of giving an equal weight to each market and growth point. In reality, some markets are larger than others and, although a farther distance away, may be more important because of their size. To account for the different size of markets and growth points, an index of interaction potential is included and defined as:

$$\text{I. P. (i,M)} = \sum_{j=1}^M \frac{P_i \cdot P_j}{t_{ij}}$$

where

I. P. (i,M) = interaction potential between growth point i and M regional markets,

$P_i$  = population of growth point i,

$P_j$  = population of regional market j,

$t_{ij}$  = minimum path travel time from growth point i to regional market j,

$i = 1, 2, 3, \dots n$  (growth point in West Virginia), and

$j = 1, 2, 3, \dots M$  (regional market outside West Virginia).

The index of interaction potential is thus based on the structure of the transportation network and the population of the growth points and markets.

The two indices were computed for the 1950 base network, the 1965 network with part of the Interstate System completed, and two 1975 networks. The 1975A network assumed the completion of only the Interstate Highway System, whereas the 1975B network assumed the completion of both the Interstate and Appalachian Development Systems. Minimum time paths were computed between each growth point and each regional market. The travel times were then available for the two indices describing the locational advantage of places resulting from implementing a particular highway network structure.

#### Analysis of the Structure of the West Virginia Highway Network

The two indices computed for the four networks will be used to analyze the three effects stated previously.

Accessibility to Markets—Accessibility measures the locational advantage of a growth point in relation to surrounding regional markets. It is, therefore, a good measure of the effect of transportation improvements on the development of a stranded area such as West Virginia. The importance of accessibility to markets in industrial location decisions has been stated previously. Furthermore, most consequences resulting from highway improvements in a developed economy can be traced directly to the locational advantage of a given place relative to other places. Figure 3 traces the patterns of accessibility to major markets for the four highway networks considered.

Comparison of the 1950 and 1965 accessibility patterns reflect the impact resulting from the construction of the West Virginia Turnpike and the first sections of the Interstate Highway System. During this time period, the average travel time to markets from most areas of the state decreased by at least one hour. Some sections in the southern part of the state located near the Turnpike indicate an average travel time decrease of more than two hours. The pattern of accessibility did not change radically during the 1950 to 1965 period; the northern panhandle (region four) remained the most accessible area to major markets, and the most southern part of the state (region nine) remained the least accessible area.

Patterns of accessibility produced by the 1975A network decreased average travel time to markets by 2 hours in most areas of the state when compared to the 1950 pattern. The average travel time to markets was more than 3 hours lower in some sections of region nine. However, the relative locational advantage of most places remained unchanged. The difference between the most accessible and the least accessible growth point remained about four hours.

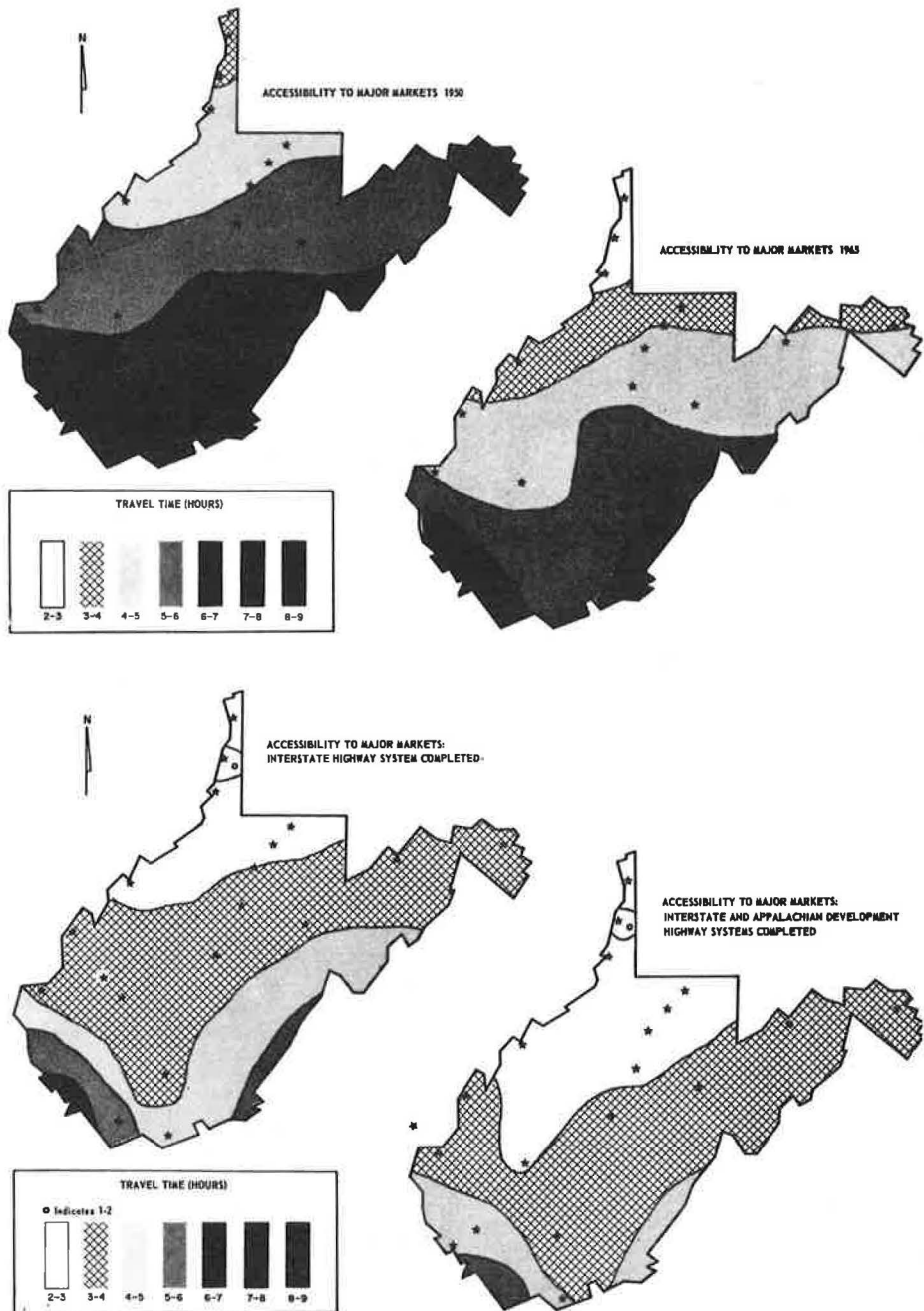


Figure 3. Accessibility to major markets.

Completion of the Appalachian Development Highway System (1975B network) reduced the difference between the most accessible and the least accessible growth points to just over three hours. Thus, construction of the Appalachian Development Highway System tends to equalize accessibility differences between regions of the state. However, even with the completion of the Appalachian Development Highway System, the relative position of each growth point remains similar to 1950, only the differences are smaller.



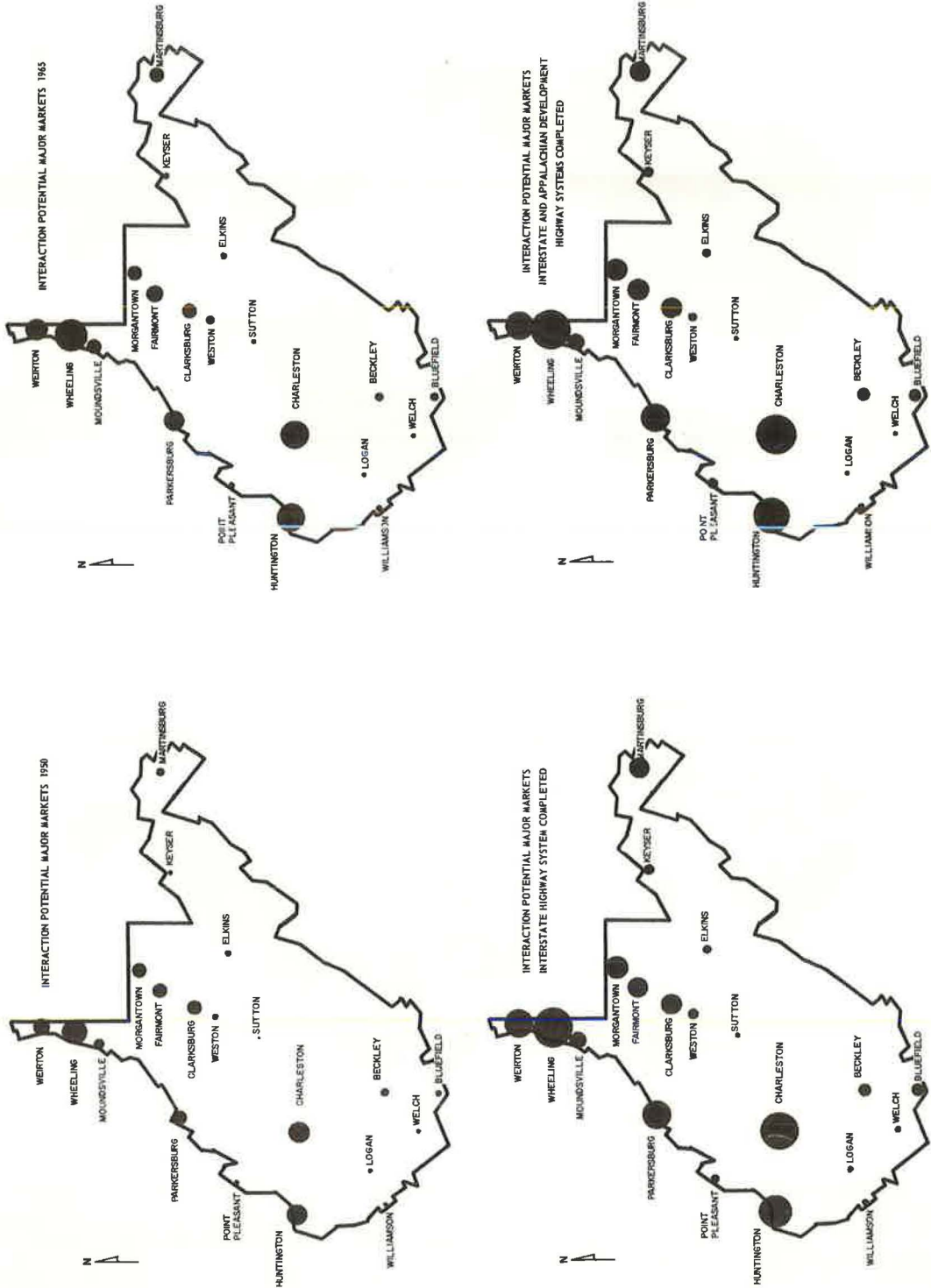


Figure 4. Interaction potential major markets.

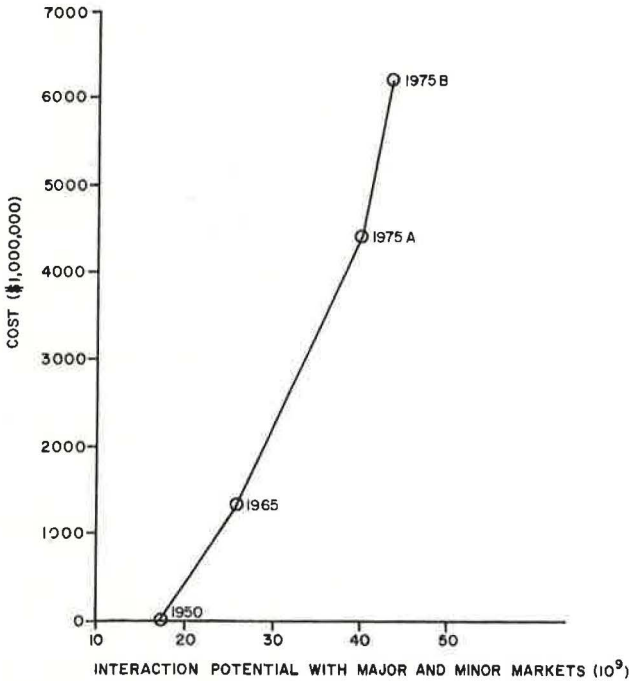


Figure 5. Change in interaction potential with major and minor markets of 23 West Virginia cities vs highway construction cost.

Interestingly, analogous results were achieved when analyzing the changes in accessibility of West Virginia growth points to both major and minor regional markets.

Interaction Potential—Interaction potential is a measure of the potential flow of people and goods between West Virginia growth points and regional markets. Figure 4 displays the interaction potential between major markets and each West Virginia growth point for the four networks considered.

Between 1950 and 1965, the interaction potential remained approximately identical for regions five, seven, and nine. However, substantial increases in interaction potential were noticed for Charleston, Huntington, Parkersburg, and the northern and eastern panhandles. As a result of completing the Interstate Highway System (1975A network) and the anticipated population growth of West Virginia cities and surrounding regional markets, all

growth points showed a substantial increase in interaction potential with the exception of Sutton, Welch, Williamson, and Logan. Construction of the Appalachian Development Highway System had almost no effect on the interaction potential of West Virginia growth points. Williamson, Charleston, Huntington, Morgantown, Fairmont, and Clarksburg only indicated a slight increase in interaction potential. Otherwise, no noticeable change was apparent.

The interaction potential considering both major and minor markets was always larger than the interaction potential with only major markets because of the greater number of markets. Although the absolute value of the interaction potential was altered, the relative position of growth points remained the same regardless of whether or not minor markets were considered.

Locational Advantage of Growth Points—In summary, the locational advantage indices show that significant changes are taking place. The locational advantage of all growth points increase with the construction of the two new highway systems. However, the relative locational advantage of growth points in the state do not change significantly from 1950 to 1975. The more accessible growth points in 1950 should remain more accessible in 1975, and the least accessible growth points in 1950 should remain least accessible in 1975. It is becoming more and more difficult to radically alter accessibility and interaction patterns between cities. However, changes are possible and alternative systems can be tested to measure the effects of each alternative on the locational advantage of growth points.

#### The Relationship Between Network Structure and Construction Costs

An analysis was made of the relationship between the construction costs for transportation improvements and the indices of locational advantage. The cost of constructing the Interstate System was assumed to be \$1,500,000 per mile, and the cost of constructing the Appalachian Development Highway System was assumed to be \$1,250,000 per mile.

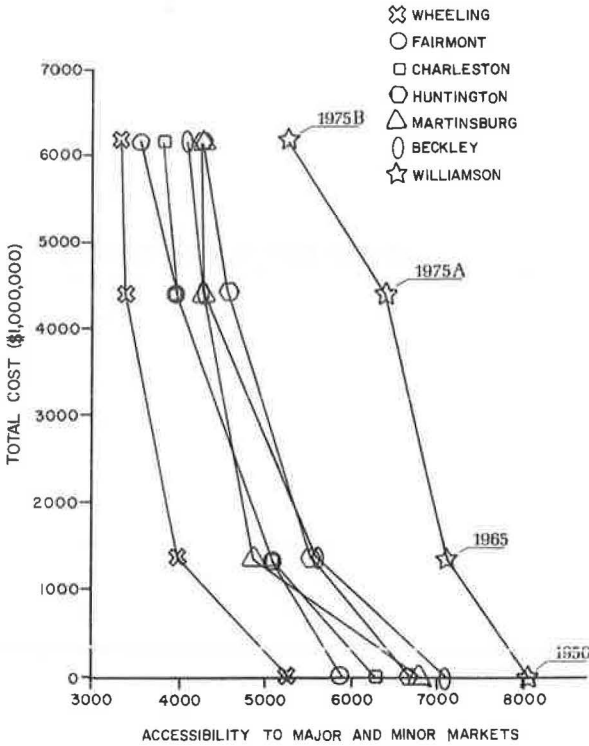


Figure 6. Change in accessibility to major and minor markets vs highway construction cost.

Virginia growth points. The plot indicates that certain highway improvements will tend to aid some growth points more than others. In 1965, with only some sections of the Interstate System completed, Martinsburg became more accessible than either Fairmont, Charleston, Beckley, or Huntington. After the Interstate Highway System is completed, the situation will change as Charleston and Fairmont become more accessible. Beckley and Martinsburg will then be equally accessible and Huntington will remain less accessible. Finally, completion of the Appalachian Development Highway System will change the relative locational advantages of these five cities. As in 1950, Fairmont and Charleston are the two most accessible cities, but they are now followed by Beckley, Martinsburg, and Huntington, in that order. The net effect, then, has been to increase the locational advantage of Beckley over Martinsburg and Huntington.

A comparison of the relative accessibility of West Virginia growth points in 1950 and 1975 indicated that, although changes have occurred, Wheeling remained the most accessible growth point and Williamson the least accessible. The added cost of the Appalachian Development Highway System does not provide any further accessibility to cities such as Martinsburg and Wheeling. However, the Appalachian System was of particular importance to Williamson, because this city was lagging far behind in relative accessibility even after completion of the Interstate Highway System.

The above analysis indicates how the locational advantage of West Virginia cities will shift through programming of significant West Virginia highway construction projects. In the case of West Virginia and other stranded areas, information of this nature can assist in selecting the highway alternatives that provide the greatest increase in accessibility to those cities demonstrating the highest growth potential when measured by available infrastructure, human resources, etc. A trace of accessibility patterns might significantly alter highway investment policies under the selected strategies of (a) maximizing aid to growth points demonstrating greatest potential, or (b) equalizing the regional growth prospects for all urban areas considered.

Figure 5 shows a plot of the estimated construction cost required to increase the interaction potential with major and minor markets for the 23 West Virginia growth points considered in this study. The results indicate that the rate of increase in interaction potential diminishes as the number of miles of high-type facilities increases. Construction of the first sections of the Interstate Highway System, as reflected in the incomplete 1965 network, increases interaction potential at a much higher rate per dollar of construction funds than the final additions to the Interstate System or the supplemental Appalachian Development Highway System. An analysis of this nature should assist the transportation planner in evaluating the impact of alternative systems. It might also be possible to determine how many miles of freeway should be provided for the Region. If additional funds are available, they might be used in upgrading feeder roads or improving the air network with greater returns.

Figure 6 shows the changes in accessibility for a sample of West

This type of analysis can and should be considered along with the traditional economic and social consequences generally enumerated in evaluating alternative transportation investments. This information is not a replacement for the traditional economic analysis. Rather, it is additional information that should be included with traditional consequence measures in order to provide a package of information to the decision-maker that will assist him in reflecting on all data that might be relevant to his decision. Where strong statements of regional goals have been previously specified, as in West Virginia, the transportation alternatives must be evaluated within the context of those regional goals. The importance of the indices developed in evaluating alternative systems lies in the care that was exercised to select indices reflecting regional goals.

### CONCLUSIONS

This paper suggests that, insofar as possible, the evaluation of alternative transportation systems should be based on analytical techniques reflecting regional goals. The indices of the locational advantage of growth points in West Virginia indicate that the proposed highway improvements in West Virginia will have an impact on regional accessibility patterns. The importance of considering this kind of information when a transportation investment is to serve specified development objectives (as in the case of the Appalachian Development Highway System) is obvious.

The value of the procedure used is based on the relationship between the indices presented and the effect of transportation improvements in a stranded area such as Appalachia. The possibilities for utilizing a similar procedure in other areas are many. However, the indices developed must be based on a study of the role of transportation in achieving specified goals. For example, the economic growth of depressed areas and central cities in urban regions might become an important national goal in the future. The evaluation of urban transportation systems could then consider the increase in accessibility of depressed areas to industrial centers as one important criteria in the selection of a system. The proposed procedure presented in this paper can then supplement the traditional economic analysis and other consequences of transportation improvements whenever strong regional goals are specified.

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